REEF FISH POPULATIONS OF THE INVESTIGATOR GROUP, SOUTH AUSTRALIA: A COMPARISON OF TWO CENSUS METHODS

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Summary

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Fish populations were censused at five islands or reefs in the Investigator Group mainly in 1982 and 1983. The distribution of abundance of species was examined by visual census along belt transect lines and by recording the log abundances of fishes observed for a fixed time period in a variety of habitats.

The belt transect method gives consistent and hence repeatable results although it does not completely sample the fish community. Log abundance counts yield more species per site because the diver covers a larger area and presumably samples more habitats. The latter method therefore seems most suitable for preliminary survey work.

KEY WORDS: Reef fishes, census methods, Great Australian Bight.

Introduction

The composition and structure of reef fish communities are an important aspect of reef ecology, but have been largely neglected in southern Australian temperate waters. Most reefs are subject to spearfishing to varying extents (Johnson 1985a, b) so that there are few places where unexploited fish assemblages occur. Cruises to the Investigator Group of islands in the eastern Great Australian Bight from 1982 to 1985 gave the opportunity to census reef fishes at places which are rarely fished (Fig. 1). Baseline information on these fish assemblages will be useful both in providing a general picture of the abundance of reef fishes in this poorly known region and as a comparison with mainland sites which are exploited by man. This

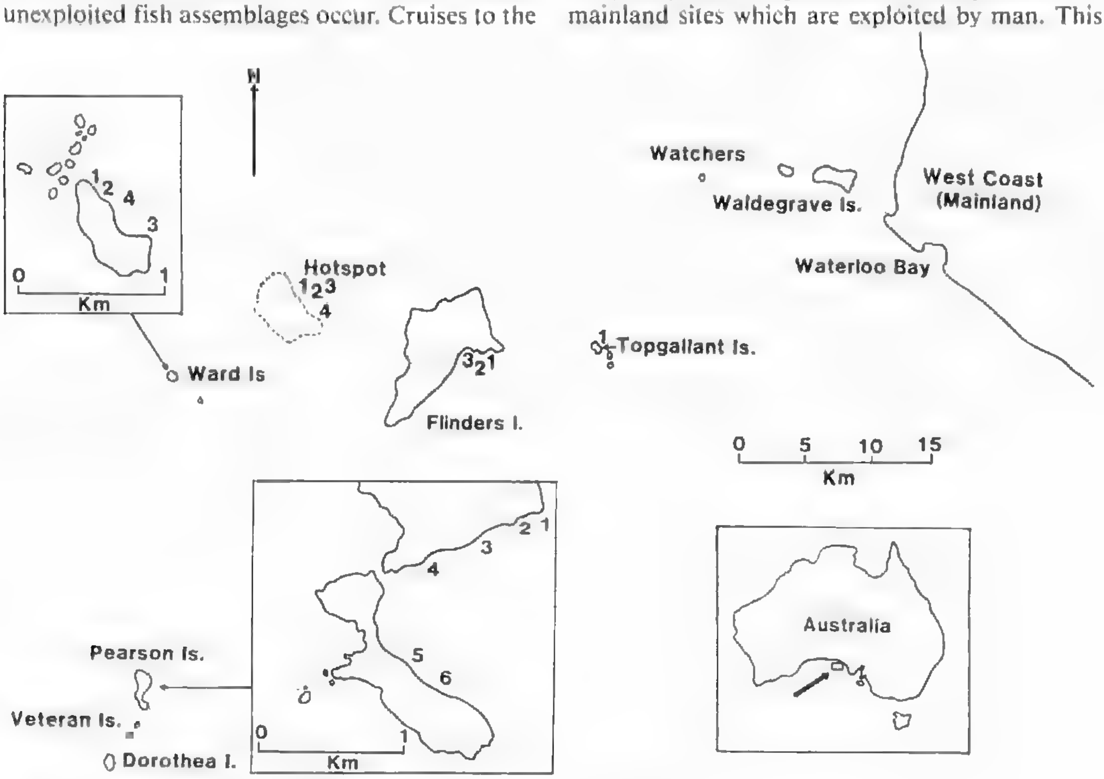

Fig. 1. Islands of the Investigator Group with location of censuses

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study supplements that of Kuiter (1983) who recorded 90 species of fish from this group of islands. Elsewhere, fish species' lists have been given by Last (1979) and Kuiter (1981) for the Kent Group in Bass Strait, and Edgar (1984) for other Tasmanian locations.

In this paper we use two visual census methods to provide data on the abundance of fishes at numerous islands in the Group and compare the relative effectiveness of each.

Materials and Methods

Two methods were used to census fish.

1. *Log-Abundance Counts*

The diver swam at a constant speed along a predetermined depth contour 'sampling' a variety of habitats, and recorded on a slate the numbers of fish of each species seen during a 30 minute swim. Numbers were recorded on a $\log_3$ abundance scale, i.e.

Scale	*Numbers*	*Scale*	*Numbers*
1	1	5	10–27
2	2–3	6	28–81
3	4–9	7	>243
4	10–27		

The method is described in greater detail by Edgar (1981).

2. *Belt transect*

A 50 m surveyor's tape was placed on the sea bed perpendicular to the depth contours of the reef. The diver swam along one side of the tape and returned along the other, recording on a slate the identity and size of each fish within an estimated band width of 5 m bordered by the tape. The method is described by Quast (1968) and can be carried out much more rapidly than the original double line transect of Brock (1954). It has been used by a number of authors, including Russell (1977) and Willan *et al.* (1979) in New Zealand, and gives an estimate of the numbers of fish in an area of 500 m^2 covered by the census. Sale & Douglas (1981) considered the method gave reasonably precise and repeatable results, although its precision in terms of species or numbers does not exceed about 80%.

In order to compare replicate censuses at one site and censuses in different years at the same site the percent similarity (PS) index was calculated as follows: $PS = \frac{2W}{A+B}$ where A is the sum of the measures for all species in one sample, B is the similar sum for all measures in the second sample, and W is the sum of the lesser measures for each species occurring in both samples. The measure used is log transformed (n+1) numbers. This transformation reduces the effect of a few very abundant species which would otherwise swamp an analysis (Field & McFarlane 1968). The measure has been used for visual census data by Sale & Douglas (1981).

To determine if an optimal number of censuses existed, the increase in PS values and in number of species by stepwise pooling of censuses were computed for the data at Topgallant I. PS values for all possible combinations of censuses were calculated and the means and standard errors obtained. PS comparisons were between pooled censuses (from 1–5) and all censuses combined.

Site Descriptions

Topgallant I.

The lee of this island drops sharply to a depth of about 30 m where broken rock and sand occur. At the site studied large, irregular limestone boulders lie scattered down the slope, and bear algal assemblages dominated by *Ecklonia radiata, Acrocarpia paniculata, Cystophora* spp or *Sargassum* spp as described for Pearson I. by Shepherd & Womersley (1971).

Hotspot

This is an extensive submerged reef, with several peaks awash at low water. Site 1 is on creviced granite bottom with high relief (to 5 m) of blocks and boulders. Sites 2–4 are of moderate relief (1-2 m) with numerous blocks and boulders. All sites are exposed to considerable wave energy from swell. Algal assemblages are as described for Topgallant I.

Ward I.

Site 1 is on sloping granite bottom of low relief. Site 2 is partly rubble or boulder bottom, partly of high relief (to 3 m) platforms, heavily undercut to form caves and overhangs. Site 3 is similar to Site 2 but with a greater proportion of low boulders. Site 1 is exposed to strong swell and Sites 2 and 3 to moderate swell. Algal assemblages are as described above.

Pearson I.

All sites have sloping granite bottom. Site 1 has many blocks and boulders 1–3 m high, Site 2 has many blocks up to 2 m high and Sites 3–6 have generally low relief with occasional boulders up to 1 m high. Wave energy from swell decreases from Site 1 (high) to 6 (low). Algal assemblages are as described above.

TABLE 1. *List of fish species observed during the surveys, with results of log abundance at various sites;* H - herbivore; O - omnivore; C - benthic carnivore; P - planktivore.

Scientific name	Common name	Feeding type	PEARSON I.				FLINDERS I.			WARD I.		HOTSPOT			
			8/4/83				10/4/83			11/4/83		13/4/83		14/4/83	
			Site				Site			Site		Site		Site	
			2	3	5	6	1	2	3	1	2	1	2	1	4
Myliobatis australis Macleay	Eagle Ray	C			1							1			
Centroberyx lineatus (Cuvier & Valenciennes)	Swallow-tail Snapper	P		5		5		1		4	5				
C. gerrardi (Guenther)	Red Snapper	C			1	2	2	1							
Phyllopteryx taeniolatus (Lacepede)	Sea Dragon	P		1											
Pempheris multiradiatus Klunzinger	Common Bulls-eye	C	5	5	4	5	5	6		5	6	3	5		
Upeneichthys vlamingii Cuvier & Valenciennes	Goatfish	C	4	3	4	5				2		4	4		1
Vincentia conspersa (Klunzinger)	Southern Cardinalfish	P	4	3	3	2									
Dinolestes lewini (Griffith)	Long Finned Pike	C			1	1	1		2						
Pseudocaranx dentex Valenciennes	Trevally	O	See Table 5												
Enoplosus armatus (White)	Old Wife	O	4	3	3		2	2							
Pentaceropsis recurvirostris (Richardson)	Long-snouted Boarfish	C					2								
Hypoplectrodes nigrorubrum (Cuvier & Valenciennes)	Banded Sea Perch	O								1					
Caesioperca rasor (Richardson)	Barber Perch	P	3	5	4	5				5	5	2	3	4	5
Paraplesiops meleagris (Peters)	Blue Devil	C		1	1	1	2	3		1					
Trachinops noarlungae Glover	Noarlunga Hulafish	P	6	5	5	6	6	6	6	6	6				
Sillaginodes punctatus (Cuvier & Valenciennes)	King George Whiting	C		2											
Dactylosargus arctidens (Richardson)	Sea Carp	H		1											
Girella zebra (Richardson)	Zebrafish	O	5	5	3	3	3	2	2	2	3	1			3
Kyphosus sydneyanus (Guenther)	Drummer	H							2						
Scorpis aequipinnis Richardson	Sea Sweep	P	5	6	5	6	6	5	5	6	6				5
S. georgianus Cuvier & Valenciennes	Banded Sweep	P					1		1						
Vinculum sexfasciatum Richardson	Moonlighter	C		2	2	2		1	1	2	3	2			
Chelmonops truncatus (Kner)	Coralfish	C			2			1			2				
Parequula melbournensis (Castlenau)	Silver Belly	P	4	3		3			3	5	4	4	4		
Chironemus georgianus Cuvier	Kelpfish	H	1												
Dactylophora nigricans (Richardson)	Strongfish	O	3	2	1							1			
Nemadactylus valenciennesi (Whitley)	Queen Snapper	C	3	3	3	2	1								3
Cheilodactylus nigripes Richardson	Magpie Perch	C	3	4	4	4	3	3	3	4	5	4	3	3	3
Arripis georgianus Cuvier & Valenciennes	Tommy Rough	P								5					
Norfolkia striaticeps (Ramsay & Ogilby)	Common Threefin	C			1										
Parma victoriae (Guenther)	Scaly Fin	O	4	4	3	4	3	3	2	4	4	1		1	3
Achoerodus gouldii (Richardson)	Blue Groper	C	4	4	4	4		1		4	3	3	2		
Opthalmolepis lineolatus Cuvier & Valenciennes	Maori Wrasse	O			1							2	2		
Dotalabrus aurantiacus (Castlenau)	Pretty Polly	C	1	3		1			1						
Austrolabrus maculatus (Macleay)	Black Spotted Wrasse	C	See Table 2												
Pictilabrus laticlavius (Richardson)	Senatorfish	C	4	4	3	4	2		4	4	4	4	3	5	4
Pseudolabrus tetricus Richardson	Blue-Throated Wrasse	C	6	6	5	5	5	5	5	5	5	5	5	5	5
P. psittaculus Richardson	Rosy Wrasse	C	See Table 5												
Odax cyanomelas Richardson	Herring Cale	H	3	2	2	2	3	2	2	4	3				
O. acroptilus (Richardson)	Rainbowfish	O		1	2	3						3		2	
Siphonognathus beddomei (Johnston)	Bird-nose Weed Whiting	C												4	
S. caninus (Scott)	Sharp-nosed Weed Whiting	C			1	1									
Bigener brownii (Richardson)	Spiny Tailed Leatherjacket	O	See Table 4												
Scobinichthys granulatus (Shaw)	Rough Leatherjacket	O								1					
Penicipelta vittiger (Castlenau)	Tooth Brush Leatherjacket	O	2							1					
Meuschenia flavolineata Hutchins	Yellow-lined Leatherjacket	O	4	4	3	4				4	3				3
M. galii (White)	Blue-lined Leatherjacket	O										3	1	3	
M. hippocrepis (Quoy & Gaimard)	Horse-shoe Leatherjacket	O	4	4	4	4		1		4	5	3	3		4
M. venusta Hutchins	Stars & Stripes Leatherjacket	O	3	3	3	1		2		1		2			
Anoplocus lenticularis (Richardson)	Humpback Boxfish	C								1	1				
Aracana aurita (Shaw)	Shaw's Cowfish	C								2		1			
Omegophora cyanopunctata (Hardy & Hutchins)	Blue Spotted Puffer	O		2									1		
Cochleoceps spatula (Guenther)	Clingfish	C				1							1		
Number of species			23	27	30	28	16	16	15	25	18	19	12	8	11
Depth (m)			8	8	8	8	8	8	8	6	6	12	12	12	12

Flinders I.

The sites investigated by log abundance count here were close together. The bottom is relatively level with patches of sand and a few large (3–4 m), overlapping blocks forming caves. Wave exposure is low relative to the other sites. The algal assemblages are dominated by *Cystophora* spp and *Sargassum* spp.

Results

A species list, with common names, of fish observed on the various censuses is given in Table 1, together with the results of the log abundance counts for various sites. One species not seen by Kuiter (1983) i.e. *Dactylosargus arctidens* (Richardson) was recorded at Pearson I. The greatest number of species sighted during half hour periods were recorded at Pearson I. and the fish faunas at the Hotspot were found to be the least diverse. Whether changes in diversity are a function of topographic complexity, water movement, algal standing crop, or a combination of these and other factors is impossible to determine without additional censuses.

The belt transect counts of the fish species, and their mean estimated lengths, are given in Tables 2–6 for Topgallant I., Hotspot, Ward I., and Pearson I. respectively. Replicate censuses of the abundances and size structures of fish species observed along a single belt transect line show close correspondence, regardless of whether they were carried out by different divers or the same diver (PS = 0.72 for census on 10.iv.1983 at Topgallant I. (Table 2), and PS = 0.74 at Site 2 and 0.77 at Site 3, Ward I. (Table 4); PS = 0.71 at Site 1 and 0.65 at Site 4, Hotspot (Table 3)). Even PS values at the same site between years were quite high (mean PS = 0.66, s.e. = 0.06 for all between year comparisons of censuses at Topgallant I.).

The increase in cumulative number of species and in PS values by stepwise pooling of censuses (Fig. 2) shows in each case even curves without breakpoints. After the first 2 or 3 censuses species accumulate more or less evenly by the addition of chance sightings of mostly individual wandering species. Further sampling would presumably lead to levelling out of these curves.

The numbers of fish species sighted during the belt transects were significantly correlated with the depth range, and hence gradient, of the transects (Fig. 3, $r = 0.56$; $P < 0.05$). In this analysis, whenever a transect was duplicated the mean

TABLE 2. *Results of belt transect censuses at Topgallant I.* n = number of fish sighted; x = estimated mean length.

Date Surveyed	1/4/82		29/3/82		10/4/83		10/4/83		21/4/85		21/4/85	
Depth Range	5–17 m		5–17 m		6–17 m		6–17 m		6–17 m		6–17 m	
Diver	KB		KB		GE		KB		KB		KB	
	n	x(cm)	n	x(cm)	n	x(cm)	n	x(cm)	n	x(cm)	n	x(cm)
Centroberyx gerrardi	2	25	4	24	2	30			7	28	2	35
Pempheris multiradiatus	1	8	1	10			1	15	5	12	155	2
P. klunzingeri	11	10	1	15								
Upeneichthys vlamingii	2	8										
Dinolestes lewini			1	15								
Caesioperca lepidoptera	1	10	6	15	5	9	3	7	38	12	42	5
Paraplesiops meleagris											1	25
Trachinops noarlungae	9	8	63	10	155	8	241	8	90	7	150	6
Girella zebra	9	26	8	21	2	25	4	8	16	23	11	23
Kyphosus sydneyanus											1	25
Scorpis aequipinnis	10	26	10	18	6	19	20	11	13	25	12	18
Vinculum sexfasciatum	1	25	3	25	1	23					3	20
Chelmonops truncatus			2	20	2	23					3	15
Dactylophora nigricans	1	30	2	38								
Nemadactylus valenciennesi	3	37	1	38							3	40
Cheilodactylus nigripes	2	30	1	25	2	18	4	27	5	25	4	27
Parma victoriae	2	18	5	15	3	17	3	19	9	18	9	18
Achoerodus gouldii	1	51	3	51	1	30	4	53	2	43	1	50
Dotalabrus aurantiacus	1	15										
Austrolabrus maculatus							2	15				
Pictilabrus laticlavius	2	18	1	20	2	11	2	15	1	20	2	20
Pseudolabrus tetricus	8	17	16	19	20	19	21	24	12	24	10	25
Odax cyanomelas			1	30					7	30	1	21
O. acroptilus									1	15		
Siphonognathus beddomei	4	15										
S. caninus					2	8						
Meuschenia flavolineata	2	30	1	30					4	31	4	31
M. hippocrepis	2	28	1	30	1	30	2	30				
NUMBER OF SPECIES	20		20		14		12		15		18	

TABLE 3. *Results of belt transect censuses at Hotspot.* n = number of fish sighted; x = estimated mean length.

Site Number	1		1		1		4		4	
Date Surveyed	1/4/82		13/4/83		13/4/83		14/4/83		14/4/83	
Depth Range	13–14 m		13–14 m		12–14 m		11–15 m		11–15 m	
Diver	KB		GE		GE		GE		GE	
	n	x(cm)	n	x(cm)	n	x(cm)	n	x(cm)	n	x(cm)
Pempheris multiradiatus	1	15								
Upeneichythys vlamingii	1	15	10	13	5	20	1	15		
Caesioperca rasor	5	18	1	15			1	10	1	10
Girella zebra	1	25			1	30				
Scorpis aequipinnis	5	26								
Vinculum sexfasciatum			2	25	1	25				
Parequula melbournensis			3	13	6	15			1	15
Dactylophora nigricans			1	71						
Cheilodactylus nigripes	1	25	2	41	4	34				
Parma victoriae	2	20			1	25	1	25		
Achoerodus gouldii	3	68	2	61	1	61				
Ophthalmolepis lineolatus			1	30	1	30				
Pictilabrus laticlavius	4	18	2	23	6	24	6	21	4	20
Pseudolabrus tetricus	5	22	11	28	15	28	4	32	6	31
Odax cyanomelas	2	28								
O. acroptilus			2	15						
Siphonognathus beddomei							10	12	2	15
Meuschenia venusta			1	18	1	18				
M. hippocrepis			1	25	1	30				
Aracana aurita					1	20				
NUMBER OF SPECIES	11		13		13		6		5	

TABLE 4. *Results of belt transect censuses at Ward I.* n = number of fish sighted; x = estimated mean length.

Site Number	4		2		2		3		3	
Date Surveyed	31/3/82		12/4/83		12/4/83		12/4/83		12/4/83	
Depth Range	20–27 m		4–12 m		4–12 m		9–12 m		9–12 m	
Diver	KB		KB		GE		KB		GE	
	n	x(cm)	n	x(cm)	n	x(cm)	n	x(cm)	n	x(cm)
Myliobatis australis			1	230	1	150	1	230		
Pempheris multiradiatus			60	8	25	13	15	13	24	13
Upeneicthys vlamingii			1	15	2	13	2	15	2	19
Caesioperca rasor	1	20	2	18	1	20	1	15		
Paraplesiops meleagris			1	20						
Trachinops noarlungae			1	8	9	5				
Girella zebra							1	25		
Scorpis aequipinnis	40	20	11	15	7	17	1	15		
Vinculum sexfasciatum			2	6						
Parequula melbournensis	3	10	2	9	8	11	13	9	13	13
Cheilodactylus nigripes			5	22	4	34	2	25	3	29
Parma victoriae			5	15	3	21	2	15	1	25
Achoerodus gouldii	2	44	7	37	3	44	5	42	3	42
Pictilabrus laticlavius	1	20	10	19	12	20	11	21	9	22
Pseudolabrus tetricus			14	21	13	25	21	19	12	25
Odax cyanomelas			3	27	2	28	2	28	2	33
Siphonognathus beddomei					1	10				
Bigener brownii					2	25	1	30		
Penicipelta vittiger									1	25
Meuschenia hippocrepis							2	24	1	30
NUMBER OF SPECIES	5		15		15		15		11	

number of fish was used to avoid pseudoreplication (see Hurlburt, 1984). The steeper transects showed greater species richness, presumably because they incorporated overhanging rocks, and hence cave dwelling fish species (e.g. *Pempheris multiradiatus*, *Pempheris klunzingeri*, *Centroberyx gerrardi*), and because habitats change relatively rapidly with depth. However, an unusually low fish species richness was found along a moderately steep transect at Site 1, Ward I. (see Table 4 and Fig. 3).

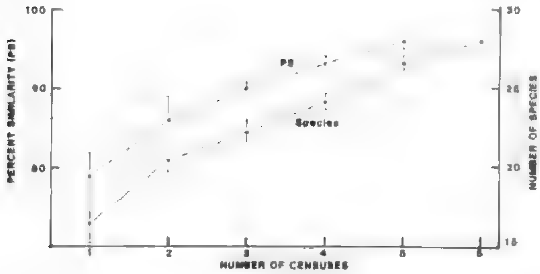

Fig. 2. Percentage similarity and mean number of species between pooled censuses (from 1-5) and all censuses combined for belt transect data at Topgallant I. Vertical bars are standard errors.

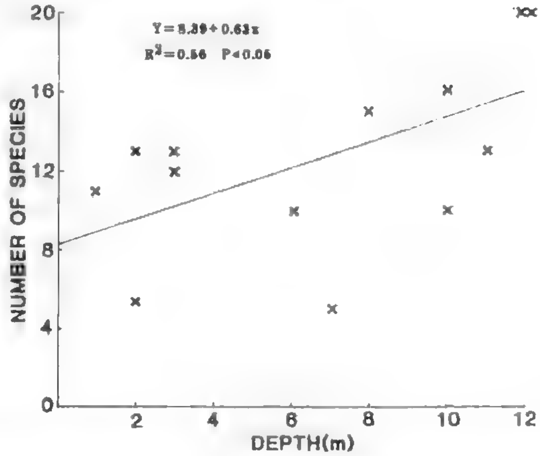

Fig. 3. Plot of number of species against depth range of the belt transect for all sites.

This transect was the only one carried out in water depths greater than 20 m, suggesting that deeper environments may be more homogeneous than those in shallow water.

Unlike the log abundance counts, there are only minor differences in the fish species richness of the belt transects between different localities in the Investigator Group (Table 6).

Discussion

The abundance of large fishes, such as the blue groper (*Achoerodus gouldii*) which was recorded in 15 out of 18 belt transects, shows that these reefs are rarely visited by spear-fishermen. These data are therefore a record of fish abundances in virtually unexploited conditions.

The two census methods produce quite different information about reef fish assemblages. The log abundance count provides a quick estimate of the relative abundances of the major fish species in an

TABLE 5. *Results of belt transect censuses at Pearson I.* n - number of fish sighted; x estimated mean length.

Site Number	1		2		3		4	
Date Surveyed	27/3/82		27/3/82		27/3/82		27/3/82	
Depth Range	10–20 m		10–20 m		5–11 m		7–10 m	
Diver	KB		KB		KB		KB	
	n	x(cm)	n	x(cm)	n	x(cm)	n	x(cm)
Pempheris multiradiatus	30	15	3	15				
Upeneichthys vlamingii					3	15	2	25
Pseudocaranx dentex							20	30
Caesioperca rasor	28	15	38	18	10	4	12	13
Trachinops noarlungae	170	8						
Girella zebra	14	30	2	25	43	12		
Kyphosus sydneyanus	40	25						
Scorpis aequipinnis	52	20	8	26			11	30
Vinculum sexfasciatum	11	25	1	25			1	30
Parequula melbournensis					25	13		
Dactylophora nigricans	1	38						
Nemadactylus valenciennesi	4	38	1	30				
Cheilodactylus nigripes	5	30						
Arripis georgianus	100	15						
Parma victoriae	11	20	1	20			1	13
Achoerodus gouldii	3	64	2	56	2	20		
Pictilabrus laticlavius					10	20	2	18
Pseudolabrus tetricus	8	20	6	24	9	26	5	24
P. psittaculus					1	8		
Odax cyanomelas							3	6
O. acroptilus							1	20
Penicipelta vittiger							1	20
Meuschenia flavolineata	5	23	3	20	8	28	2	25
M. hippocrepis	3	25			4	20		
NUMBER OF SPECIES	16		10		10		12	

TABLE 6. *Comparison of mean number (with standard deviations) of fish species at different sites by two methods.* n.d.= no data.

	Belt Transect	Log abundance count (30 mins)
Topgallant Islands	16.5 (4.1)	n.d.
Hotspot	9.6 (3.8)	13.3 (4.2)
Ward Islands	12.2 (4.4)	21.5 (4.9)
Pearson Islands	12.0 (2.8)	27.0 (2.9)
Flinders Island	n.d.	15.7 (0.6)

area, and is thus useful for comparing the fish communities at different localities.

Log abundance counts give larger species lists because the diver covers a larger area and can sample more habitats. The area searched by a diver (assuming a band width of 5 m is searched) was found by Shepherd (1985) to be 103 m^2 min^{-1}, giving a mean coverage of 3090 m^2 in 30 minutes, compared with 500 m^2 by a belt transect which takes more than twice that time.

Although the belt transect method shows significant differences in fish species richness between sites with different bottom gradients, it tells little about overall diversity differences between sites. Belt transects are useful nevertheless because they provide quantitative information about fish abundances and size structures which can be used for estimating the fish standing stock (see Willan *et al.* 1979). Such estimates, however, are approximate because the diver relies on visual estimates of fish length and transect width. Moreover, some fish are attracted to the diver while others are repelled, and the abundances of active fish may be over-estimated because divers on adjacent transects could each record a fish passing perpendicular to the transect in front of them. Subject to these inaccuracies, the belt transect method is often the only practical method for determining fish standing stock (Quast 1968). The close correspondence between the size and abundance estimates of two divers in this survey (Table 4) indicates that the method is reasonably accurate.

Two or three replicate belt transects will generally be needed because of the patchy distribution of reef fish and the limitations inherent in the method. Like Sale & Douglas (1981), we found that a single census was inadequate, with only a gradual improvement with replicate censusing. There is no obvious "breakpoint" which might be used to argue for an optimal number of replicate censuses.

The choice between the two census methods is therefore one of purpose. A log abundance count will provide more information about the fish diversity in much less time and is therefore more suited to preliminary surveys, particularly when carried out at a number of different depths. If an accurate census of fish in a given habitat is required for standing stock information, or if a single site is to be censused over a period of time to determine seasonal or annual variation, then the belt transect method is indicated.

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